The Healthy Large Intestine

Introduction

This lesson introduces the large intestine, with a focus on the colon. We'll cover their gross anatomy, histology, and vasculature, and discuss the physiology of colonic movement and absorption. We'll close with the defecation reflex. The information in this lesson is integral to the subsequent three lessons.

We also perform a vocabulary exercise in this lesson, using synonyms for arterial perfusion. We often strive to maintain clarity throughout the curriculum by not using synonyms. However, this lesson provides an excellent opportunity for such an exercise—there are many instances of perfuse, irrigate, feed, etc.

Gross Anatomy

The large intestine is divided into four segments: the cecum, colon, rectum, and anus. The colon is further subdivided into an ascending, transverse, descending, and sigmoid colon. The ileum terminates in the right lower quadrant and is connected to the cecum (the first segment of the large intestine) by a sphincter named the **ileocecal valve**. This separates the bacteria-free small intestine from the bacteria-rich large intestine.

The **colon** is the main subject of this lesson. The **ascending colon** ascends on the right side of the abdomen to the **hepatic flexure**, where it makes a 90-degree turn to become the **transverse colon**. The transverse colon is connected to the stomach by the greater omentum (we will have a long embryological talk later in the GI module). At the **splenic flexure,** the colon makes another 90-degree turn to descend on the left side of the abdomen as the **descending colon**, where it becomes the **sigmoid colon**. Then there is a sharp turn to the **rectum**, which is continuous with the **anal canal**. The external anus, derived from ectoderm, is not part of the gut tube.

The gross appearance of the outside of the colon is unique to the GI tract in that it demonstrates taeniae coli, haustrations, and epiploic appendages.

Taeniae coli are thick ribbons of smooth muscle that run longitudinally and conspicuously along the outside of the colon. There are three of them. They are equidistant from each other. They aren't simply lying atop the muscularis externa, they ARE the longitudinal layer of the muscularis externa, all bunched up. Periodically, these ribbons of muscle penetrate the circular muscle of the muscularis externa. This separates distinct bands of the colon that can contract independently of one another. The myenteric plexus lies between the circular and longitudinal layers. At any given time, some segments of the colon are contracted, bunching up the colon in the contracted segment, while other segments are relaxed. This pattern of contractions and relaxations gives the colon its wrinkled, or pouched, appearance. Each "pouch" is called a **haustrum**, which is discussed in detail later under Colonic Movement. The taeniae coli do not make up the entirety of the longitudinal muscle layer, as a thin band of longitudinal muscle connects the taeniae, covering the circular muscle and myenteric plexus of the muscularis externa.

Epiploic appendages are attached to the taeniae coli. They are fat-filled sacs of peritoneum. They serve no purpose other than to facilitate the identification of the colon as the colon.

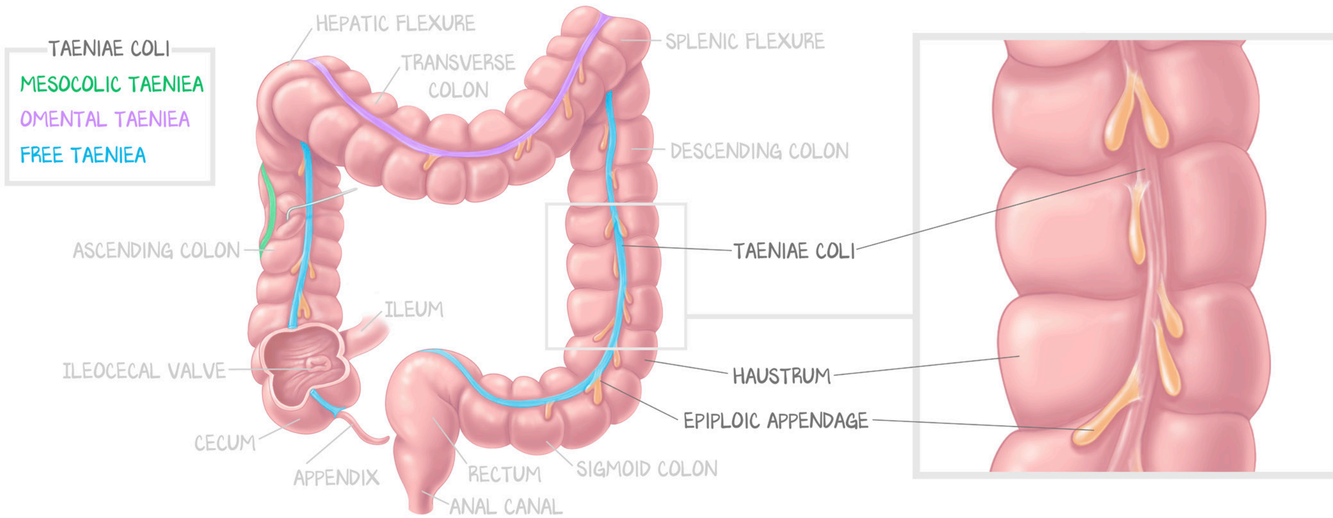

Figure 11.1: Anatomy of the Large Intestines
The various segments—cecum, ascending colon, transverse colon, descending colon, sigmoid colon, and rectum—in their relative anatomic positions in the abdomen with the surrounding organs removed. Those features that make the colon unique are also shown—taeniae coli, haustra, and epiploic appendages. The rectum and anal canal do not demonstrate these features.

Cecum and appendix. The cecum is a sac-like structure that is suspended inferior to the ileocecal valve, from which it receives luminal contents. It begins the function of the large intestine—water absorption. Attached to the inferior segment of the cecum is the **appendix**. The appendix is a winding tube that contains **lymphoid tissue,** suggesting an immunological function. It is considered to be **vestigial** and is removed in any abdominal surgery. If bacteria get closed off within that tube, they can grow. Growing bacteria in the appendix provokes **appendicitis**.

The **rectum** opens into the **anal canal**, which is the end of the large intestine. The rectum and anal canal are involved in the **defecation reflex** discussed later in this lesson.

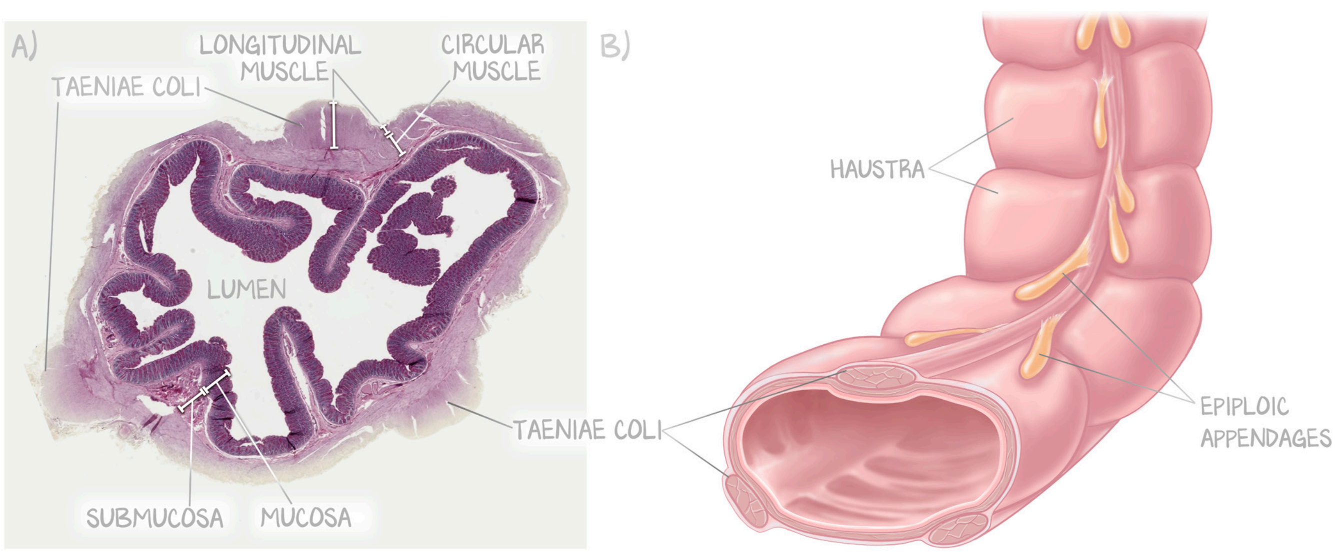

Figure 11.2: More Colon Anatomy
(a) Labeled and unlabeled histological cross-sections of the ascending colon. Notice the relatively large lumen (L), and the familiar mucosa (M), submucosa (S), and circular portion of the muscularis externa (M), but the unique bunching of the longitudinal muscles into three distinct bands: the taeniae coli (T). (b) The same concept illustrated in a three-dimensional perspective and at an oblique angle to ease understanding of the flat, two-dimensional histologic section.

The Pectinate Line

Above the pectinate line is the gut—involuntary smooth muscle, parasympathetic regulated, columnar absorptive epithelium, portal circulation. It comes from **endoderm**. It is the hindgut. Below the pectinate line is skin—voluntary skeletal muscle, stratified squamous epithelium, drains to the vena cava. It comes from **ectoderm**. The only two places where endoderm (gut lining) and ectoderm (skin) come together are the tongue and the pectinate line. We discuss defecation and colon movements below, but in short, you feel the urge to defecate because stool is moved into the rectum, and the internal anal sphincter opens. You choose the time of release by the contraction (holding it in) or relaxation (letting it go) of the external anal sphincter. The external anal sphincter is skeletal muscle and under somatic control. The internal anal sphincter is smooth muscle and under autonomic control.

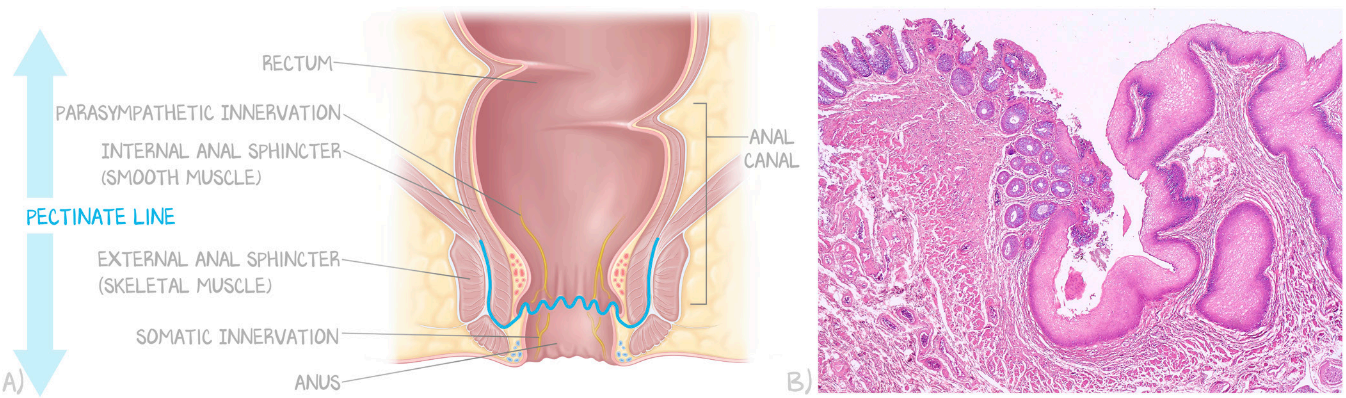

Figure 11.3: The Pectinate Line
(a) Conceptual illustration of the pectinate line. Above the line is endoderm-derived, gut tube tissue—smooth muscle, visceral nerve innervation, and tubular simple columnar epithelium. Below the line is ectoderm-derived skin tissue—skeletal muscle, somatic nerve innervation, and keratinized stratified squamous epithelium. (b) Histology of the pectinate line demonstrating both the simple columnar epithelium that makes crypts (tubular) and the nonkeratinized stratified squamous epithelium that does not make crypts. This brief stint of nonkeratinized epithelium quickly gives rise to keratinized epithelium (not shown).

The pectinate line is often depicted as a horizontal line in images. Histologically, there is a literal line—an abrupt change from stratified squamous to columnar absorptive tissue. From the perspective of the lumen, there is above and below the pectinate line, as marked by the histologic transition. But outside the lumen, the muscles of the internal and external anal sphincters are not chopped in two by an imaginary line. Instead, all of the smooth muscle that is the internal anal sphincter is "above" the pectinate line, whereas the skeletal muscle of the external anal sphincter is "below" the pectinate line. All the involuntary smooth muscle is deep to the skeletal muscle.

The clinical correlation of the pectinate line is hemorrhoids. **External hemorrhoids itch and hurt** but don't bleed, whereas **internal hemorrhoids bleed** but do not hurt or itch. External hemorrhoids are below the pectinate line and innervated by somatic sensory nerves, so the patient is aware of their presence. In contrast, internal hemorrhoids are above the pectinate line, without somatic innervation. Both types of hemorrhoids can bleed, of course, but the old surgeon's adage helps distinguish the two based on the innervation.

Vasculature

The colon is formed by both the midgut and hindgut. The midgut ends at the start of the distal third of the transverse colon; the first two-thirds belong to the midgut. The midgut is fed by the **superior mesenteric artery** (SMA). The **ileocolic** branch irrigates the appendix and cecum. The **right colic** branch of the SMA irrigates the ascending colon.

The **middle colic** branch of the SMA feeds the proximal two-thirds of the transverse colon (midgut) and forms an anastomosis with the left colic branch of the inferior mesenteric artery. From the distal third of the transverse colon to the rectum and anus above the pectinate line (hindgut) is fed by the **inferior mesenteric artery** (IMA). Following the path of the large intestine, the **left colic artery** irrigates the splenic flexure and descending colon. The **sigmoid** artery of the IMA feeds the sigmoid colon. The **superior rectal** artery of the IMA perfuses the rectum. Each artery forms an anastomosis with the branch next to it.

Even though the rectum is above the pectinate line, the most distal segment of the rectum is not irrigated by a branch of the aorta. Instead, the **inferior rectal arteries** and **middle rectal arteries** are supplied by the **iliac arteries.**

Both the SMA and IMA start irrigating the distal edges of their segments first (SMA starts at the cecum, IMA at the rectum), then fan out towards one another to form an anastomosis near the splenic flexure. Therefore, the **splenic flexure** is at the very distal end of the irrigation of both the middle colic and the left colic branches, the region of the colon that is most distal to the SMA and IMA. This creates a **watershed area**. If either the SMA or the IMA is working, the watershed area is left unaffected, supplied by the anastomosis with the other. But in periods of systemic hypotension, where flow through both the SMA and IMA is compromised, the area to get the least blood supply is the watershed area. **Ischemic colitis**, caused by systemic hypotension, is most likely to occur at the splenic flexure. This presents as painless bloody diarrhea. The bloody diarrhea of ischemic colitis is rarely life-threatening. The hypotension that caused the ischemic colitis is more of a problem than the ischemic colitis itself. Ischemic colitis can be caused by atherosclerosis—any vessel can be blocked. But we want you to separate ischemic colitis—hypotension-induced infarction of the watershed area with painless bloody diarrhea—from mesenteric ischemia—atherosclerosis of the SMA leading to intestinal angina, ischemia, and pain with eating, which could result in infarction, pain out of proportion to physical exam.

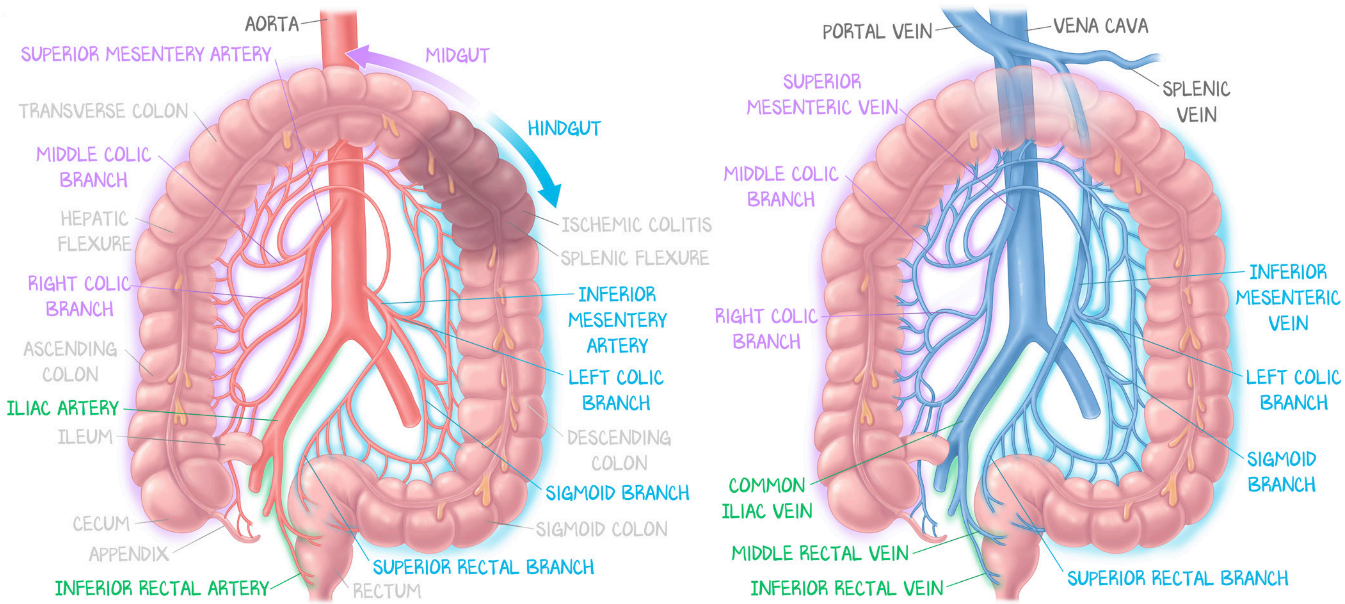

Figure 11.4: Colon Vasculature
This color-coded illustration identifies the superior mesenteric artery and vein, inferior mesenteric artery and vein, and internal iliac artery and vein. In the left panel, structures labeled in purple are associated with the SMA and irrigate the ascending colon and proximal two-thirds of the transverse colon. Structures labeled in blue arise from the IMA, serving the rest of the colon and distally to the top of the anus. Labeled in green are the branches of the iliac arteries, which perfuse the most distal anal canal. In the right panel, the veins drain either directly into the portal vein as the superior mesenteric vein and its branches (purple), into the splenic vein before the portal vein as the inferior mesenteric vein and its branches (blue), or into the caval system (green).

The veins fairly closely mirror the arteries, with a few exceptions. The **inferior mesenteric vein** drains to the splenic vein before the portal vein, whereas the **superior mesenteric vein** drains directly into the **portal vein**. The **middle and inferior rectal veins** drain into the internal iliac veins, which then drain to the inferior vena cava. Thus the middle and inferior rectal veins represent a location of possible portacaval anastomosis.

Midgut Embryology and Anatomy

How does the transverse colon, which starts really far away from the stomach in the gut tube, get to be so close to the stomach? The **midgut** is the lower duodenum all the way to the end of proximal two- thirds of the transverse colon. Everything in this section is supplied by the superior mesenteric artery. At week 6, there is a herniation through the umbilical ring. It goes out through the umbilical ring so it can do a **270-degree counterclockwise** turn around the superior mesenteric artery. Make two fists. Put the right fist on top of the other, right fist pointing down. You are facing the person. You are now holding embryonic gut tube—up is mouth, down is anus. Your left hand is going to be the splenic flexure. Turn your hands 90 degrees (you should be able to only go one way, clockwise). Turn them another 90 degrees. Your left hand is on top. Turn another 90 degrees. Ohhhh. Is that one hard on your left shoulder? Does it tug a little bit? Bam. Almost three 90-degree turns. Almost 270 degrees. Splenic flexure is now up and to the left (up and to the right from your perspective). Because the SMA was connected to your right hand at the start (because it started higher) and the IMA to your left hand (because it started lower), this also justifies the vasculature. That's it. Don't learn this more than you have already. The end result is the normal colon anatomy—**proximal ascending colon** on the right, **transverse colon** near the stomach, **distal descending colon** on the left, the splenic flexure a watershed territory.

Histology of the Colon

Good news, the large intestine histology is very much like the small intestine, only there are no villi, only crypts. The epithelium is **simple columnar**, with **enterocytes** and **goblet cells**. The base of the crypts is where **stem cells** are. They divide and differentiate a daughter cell into an **intermediate cell**, which undergoes several proliferations before terminal differentiation. There aren't any Paneth cells or M cells.

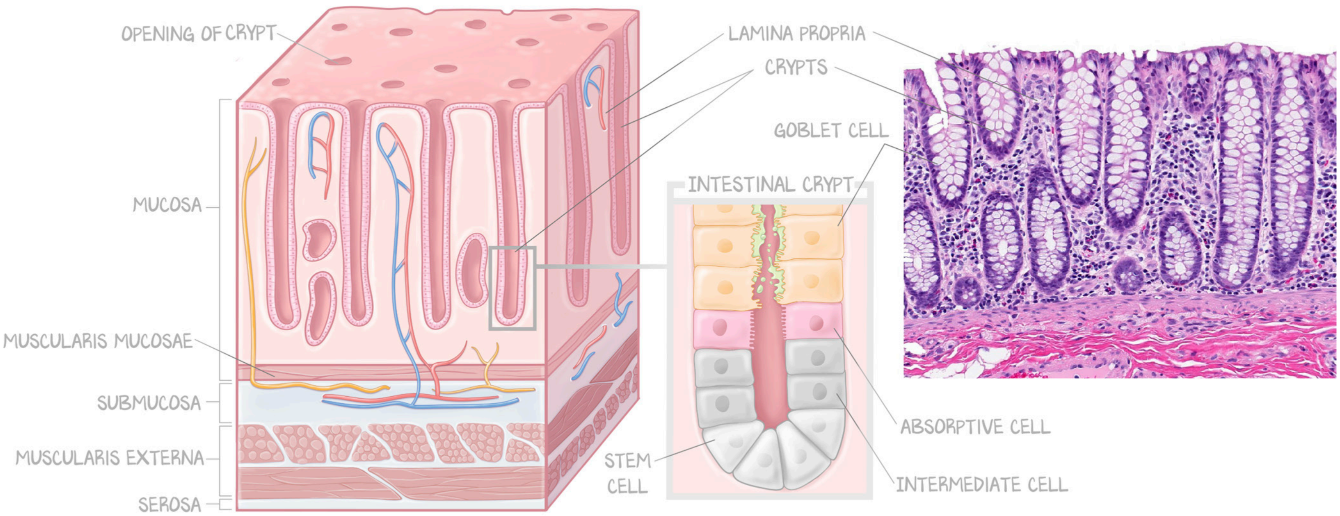

Figure 11.5: Histology of the Colon
The illustration demonstrates a familiar arrangement: crypts. The muscularis mucosae defines the boundary of the mucosa. The mucosa consists of invaginated crypts and a robust lamina propria. On histology, the abundance of goblet cells in the crypts can be appreciated (abundant white globs are goblet cells), as well as the cellularity of the lamina propria (all the blue dots are inflammatory cells defending the colonic mucosa from the colonic bacteria).

Water is absorbed via enterocytes, whereas **mucus is secreted** by the goblet cells. There are significantly more goblet cells in the colonic epithelium than there are in the small intestine. The colon does still absorb, but it mostly prepares stool for elimination, lubricating the stool to help it pass.

Colonic Movement

Haustrations result from the synchronized contraction and relaxation of colonic segments. Both longitudinal and circular muscles contribute to haustrations. This kind of movement serves to churn the colonic contents, mixing the stool and increasing the amount of stool exposed to the mucosa. This was called churning in the stomach and segmentation in the small intestine. In the colon, where there is the appearance of haustra, the same process is called haustration. Haustrations are larger and slower than either churning or segmentation.

Mass movements are the colon's version of peristalsis. It is a **propulsive movement**, but it is not peristalsis. There is no coordination of relaxation downstream and contraction upstream in successive segments that propels stool along. A mass movement is more akin to an entire stretch (up to one foot) of the colon clamping shut like an alligator biting down, shooting the contents forward and into the rectum. When mass movements occur, the haustra disappear. When the mass movement is over, they return. These happen only two or three times per day. Mass movements are meant to sweep the colon's contents into the rectum, distending the rectum and initiating the defecation reflex.

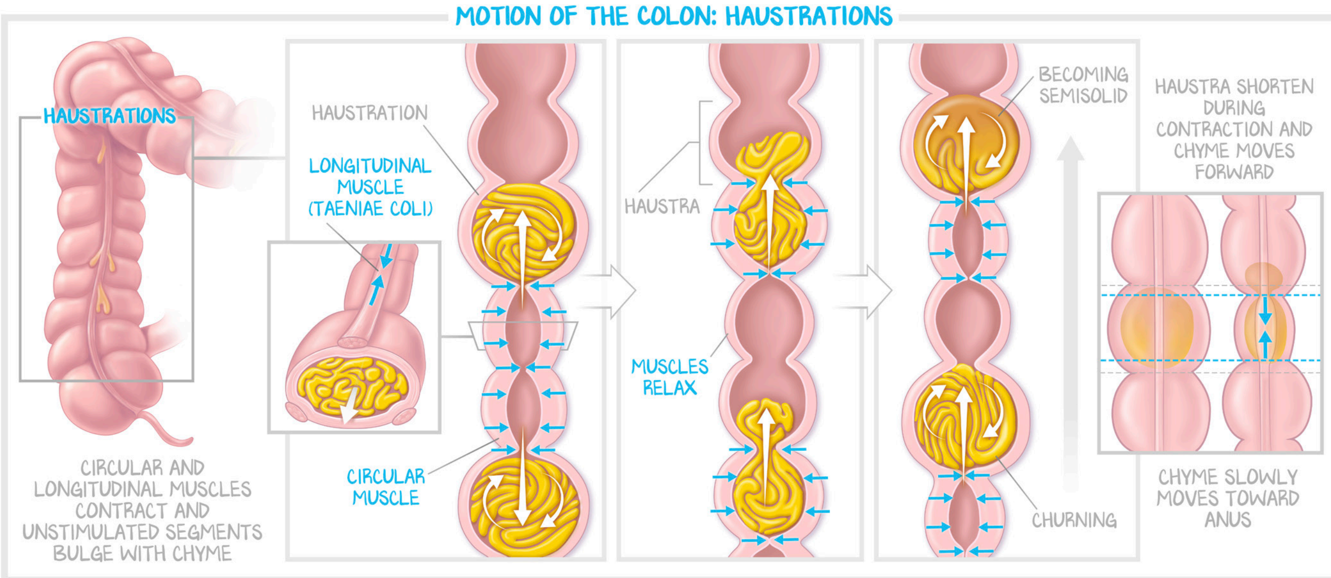

Figure 11.6: Motion of the Colon—Haustrations
Haustrations are slow, weak contractions of the circular and longitudinal muscles that serve to churn stool. The circular muscle contracts in each segment along with the longitudinal muscle. The relaxed segment just distal to the contraction accepts the stool, distending the relaxed segment. A "haustra" is a segment of relaxed colon between two segments of contracting colon. As the stool advances, it is churned, and water is absorbed by the colon, demonstrated by the fluid stool in the proximal colon on the right and the hard stool in the sigmoid colon on the left.

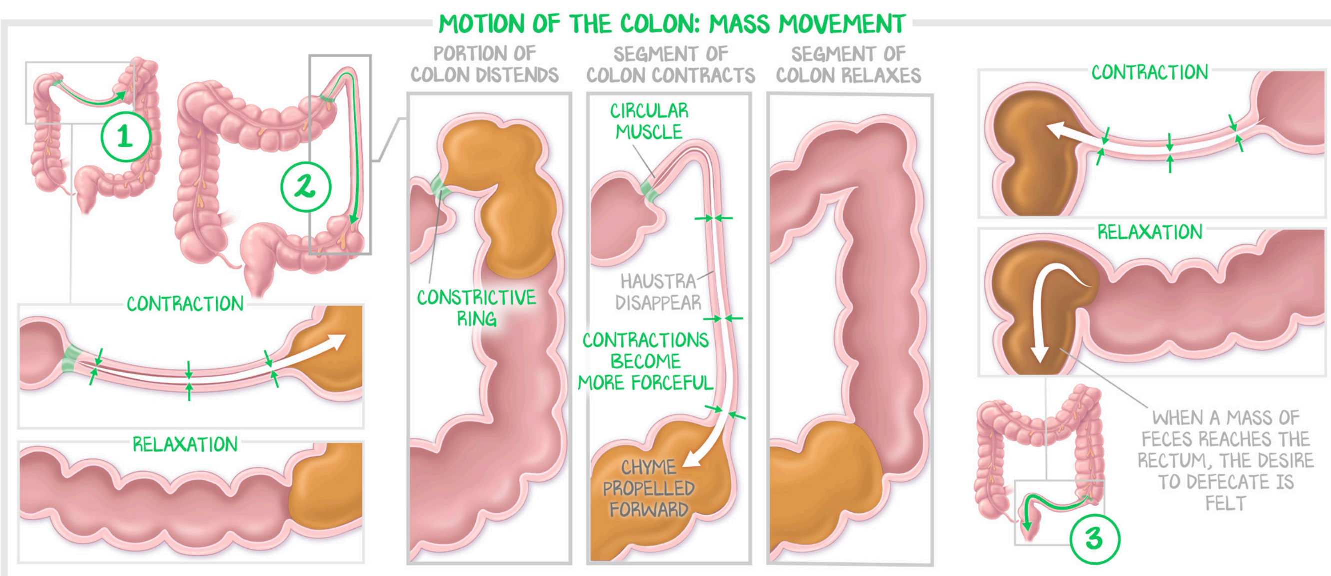

Figure 11.7: Motion of the Colon—Mass Movement
Mass movements are simultaneous contraction of a large segment of the colon. In preparation for the mass movement, the haustrations disappear, with no circular muscles contracting. (1) Like squeezing a tube of toothpaste from the bottom up, the transverse colon contracts all at once. To prevent the stool from being ejected proximally, the circular muscles just proximal to the start of the mass movement contract, forming a constrictive ring that ensures the stool is ejected into the descending colon. As the mass movement of the transverse colon ends, the haustrations return all at once. (2) The process is repeated in the descending colon—constrictive ring, loss of haustrations, contract all at once, return of haustrations all at once. (3) The mass movement of the sigmoid colon, having accepted the stool from the first two mass movements, does the same thing. The difference is that ejecting stool into the rectum distends the rectum, triggering the urge to defecate.

The **gastrocolic reflex** is a vagally mediated reflex that causes the movement of fecal contents farther along the GI tract in anticipation of new food. The gastrocolic reflex stimulates a mass movement. If the mass movement moves stool into the rectum, another motility signal is started.

The **defecation reflex** is initiated when mass movements drive fecal material into the rectum. This distends the walls of the rectum. That distention results in a vagally mediated release of **nitric oxide** at the **internal anal sphincter**. Nitric oxide relaxes smooth muscles. The internal anal sphincter opens. This dilation also gives the sensation of the urge to defecate. Stool passes into the anal canal. The sensors in the anal canal can determine what opened that sphincter—gas, solid, or liquid. It is why the anal canal has ridges (longitudinal infoldings) and sinuses (the valleys in between) running down the entire length of the anal canal. Those let you feel what has moved into the anal canal but remains above the external anal sphincter. Thus, YOU decide to open the skeletal muscle **external anal sphincter**.

The external anal sphincter is the **puborectalis**, which is a skeletal muscle sling that is oriented at a right angle to the rectum and can close it off. If the reflex is denied—the external anal sphincter is not relaxed—the rectum undergoes **receptive relaxation** (much like the stomach does, using the same mechanism) to accommodate the extra volume. The stretch receptors stop firing, the vagus stops releasing nitric oxide, and the urge to defecate goes away. It will return with the next mass movement. If stool is left in the rectum, water and electrolytes continue to be absorbed. If you hold it too long, you will develop **constipation**. Constipation and fecal impaction present with hard stool (water was absorbed) and a dilated colon (successive receptive relaxations accommodate more volume). We will talk more about that in the lesson on functional intestinal diseases.

Secondarily Retroperitoneal

Like all of the GI tract, there is a mucosa, submucosa, muscularis externa, and serosa. The serosa—the colon's adventitia lined with the mesothelium of the peritoneal cavity—exists where the colon is in contact with the peritoneal cavity. Most of the organs in the abdominal cavity are in contact with the peritoneal cavity. Most of the colon is in contact with the peritoneal cavity. But some of the colon is not. And where it is not, there is no mesothelium. This arrangement is called "secondarily retroperitoneal," which means that part of the colon does contact the peritoneal cavity and has serosa, and some part of the colon does not and has adventitia only. This happens at the ascending and descending colon.

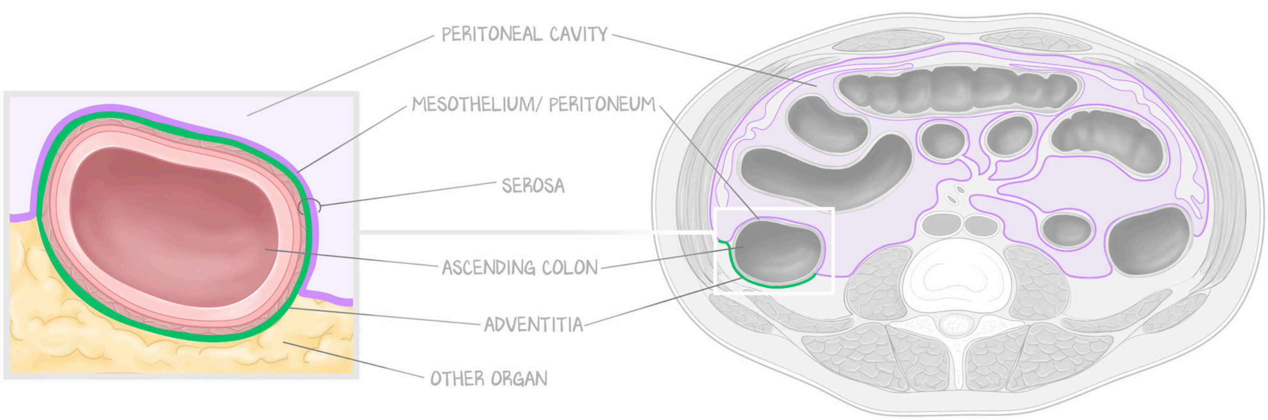

Figure 11.8: Histology and Peritoneum
The ascending and descending colon are secondarily retroperitoneal. All that means is that some part of their adventitia is covered by the mesothelium of the abdominal cavity, the same adventitia all the way around is modified only by a simple squamous epithelium to differentiate it from the adventitia. This matters because you must dissect the colon away from the connective tissue of the posterior abdominal wall where it has no serosal layer, whereas everywhere else, the colon is separated from other organs by serosa, so it doesn't need to be dissected from another organ's adventitia.

Citations

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